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THE PROTECTION OF SUGAR CANE FROM PESTS AND DISEASES.

THE spread of insect pests and diseases of crop plants has been arrested to a very considerable extent by the adoption in most countries of legislation controlling imports of plant material. Sometimes, unfortunately, the importation or even smuggling of such material by unauthorized persons still occurs. That such introductions involve grave dangers and have led to disastrous consequences in many countries cannot be denied. Example after example could be cited of the immense harm done to established agricultural industries as a result of the entry through irresponsible channels of new pests and diseases. The sugar-cane industry is no exception in this respect. In several regions of the world it has suffered considerably from accidental introductions of major pests and diseases. Thus it behoves every country where sugar cane is grown to guard against this kind of danger. In the British Empire this has been met to a very large extent by the adoption of a carefully planned system of legislation against the introduction of crop pests and diseases. Despite this legislation, an occasional insect or disease may still slip through and it then becomes a matter of considerable importance to identify and eradicate the pest or disease before it becomes permanently established. Since a knowledge of the foreign insects and diseases which are a potential hazard to the sugar-cane industry may be helpful some of the more important of these are briefly discussed below.

Cane planting material is shipped as cuttings which have been stripped of their leaf-sheaths. Thus the insects mainly to be looked for are the species living on or within the stalks. The boring moth and weevil larvae are especially to be feared. While the holes made by the larger species of larvae can be fairly readily observed those of the smaller ones are not so easily noticed. Moths deposit their eggs on the leaves but weevils insert theirs into the stalk, so that it is not possible to say definitely whether a weevil egg is present or not.

Of the borers, the most injurious pest is undoubtedly the moth borer, *Diatraea saccharalis* F., which is distributed in all the sugar-cane producing regions of North, South and Central America and the West Indies. Borers of the same genus occur in Java, India and elsewhere in the East. The larvae of this insect

do considerable damage to cane by destroying the sugar-producing tissues of the plant, thus reducing the tonnage of cane and the production of sugar. The borer by its tunnelling habits also allows the entrance of diseases which cause a further loss of sugar. The weevil stalk borers which occur in the Eastern and Western Hemispheres are also serious pests. The most noteworthy is the sugar-cane borer of Queensland and Hawaii, *Rhabdocnemis obscura* Boisd., which has been controlled in Hawaii by the Tachinid fly, *Ceromasia sphenophori* Vill., introduced from New Guinea.

The roots of cane are attacked by a number of species of white grubs, especially in Puerto Rico. One species, *Lachnosterna smithi* Arrow, was accidentally transported from Barbados to Mauritius where it became established and has since been very troublesome. Root weevils, *Diaprepes abbreviatus* L., and others of the same genus, found in the West Indies, seriously injure the root stocks of sugar cane.

The leaf insects include pests both of the gnawing and sucking kinds. There are several aphids including the corn leaf aphid, *Aphis maidis* Fitch, which transmits mosaic disease and the woolly aphid, *Oregma lanigera* Zehnt, a serious pest in Java. Other leaf insects include the froghopper, *Tomaspis saccharina* Dist., of Trinidad and the leafhopper, *Perkinsiella saccharicida* Kirk., which was accidentally introduced into Hawaii.

Unlike many of the insect pests, cane diseases cannot as a rule be detected by mere inspection of the cuttings. The diseases only appear after the cuttings are sprouted and even then they may sometimes lie dormant for many months in the growing plants, particularly of tolerant varieties before any outward signs are seen. Thus, in order to avoid introduction of diseases it is usual for the planting material imported from a foreign country to be selected by a pathologist in the country of origin. Upon arrival, all possible precautions are taken by the plant quarantine authorities, including the growing under observation of the cane for at least two generations in insect-proof greenhouses whenever these are available.

The more important and dangerous sugar-cane diseases include mosaic which nearly ruined the Louisiana sugar industry, sereh, Fiji disease, streak, leaf scald, gummosis, red rot and bacterial red stripe. It should be emphasized that most of these diseases may be introduced by cuttings, the mere inspection of which in many cases would not reveal their presence.

Mosaic, with the exception of Mauritius and some of the smaller islands of the British West Indies, is probably to be found anywhere where cane is grown commercially. Its characteristic feature is the presence of a curious "mottled" pattern upon the leaves due to the contrast of light green areas against the normal dark green of the leaf. The disease is transmitted by the corn aphid. *Sereh*, another virus disease caused the most devastating cane-disease epidemic in the history of the industry in Java. In severe form it prevents elongation of the stalk, resulting in a bunchy growth. The disease is transmitted by infected cuttings in which it is often manifested by reddish bundles in the joints as well as profuse aerial roots in the standing stalks. It was finally controlled in Java by the breeding of P.O.J. 2878 and other resistant varieties. *Fiji disease* which causes a severe dwarfing of the plant, occurs in Fiji, Australia, the Philippines, and New Guinea. Its most characteristic symptom is the presence of elongated galls on the under side of the leaves. *Streak*, also due to a virus, was reported in 1925 attacking Uba cane in South Africa; it has since been identified in Egypt, Mauritius and India. Streak, which is transmitted by a leaf-hopper, results in broken chlorotic lines or stripes on the leaves. *Leaf scald* and *gummosis* have much in common as bacterial vascular diseases. Scald has been reported from Java, Australia, Fiji, Formosa, Hawaii and the Philippines and is considered one of the most destructive diseases of sugar cane. Its danger is that it lies dormant for long periods before the characteristic narrow white streaks appear on the leaves. In the acute phase whole plants may suddenly wilt and die when the leaves present a scalded appearance. *Gummosis* occurs in Australia, Mauritius, the West Indies, Brazil and Colombia. It is recognized by characteristic yellowish-brown leaf stripes which follow the vascular bundles, and reddening of the stalk tissues in the joints. In severe infections yellowish gum will exude from the cut ends of diseased stalks. This gum causes much trouble and heavy sucrose losses in the factory. All modern canes bred by the British West Indies Cane Breeding Station are resistant to this disease. *Red rot* is found in most cane growing countries of the world but is particularly serious in India where epidemic outbreaks have occurred. The characteristic symptoms are reddening of the internal tissues, loss of colour and drooping of the upper leaves. Later the whole crown withers and dies. In the final stages the pith dries and becomes a dirty brown mud colour. *Red stripe*, although reported from many countries, has not yet been found in the British West Indies. The main diagnostic symptom is the presence of long narrow red streaks running along the leaves. The effects of the disease are much more marked on young canes than on old. It may be followed by top rot. Diseases of lesser importance include downy mildew, rust and smut.

The welfare of the cane industry in the British Empire will depend in a large measure on preventing the introduction of pests and diseases into new areas. This can only be done by the strictest enforcement of quarantine legislation and the closest cooperation on the part of everyone in preventing surreptitious importations of new varieties. Pathologists and entomologists should be notified of suspicious disease symptoms and unfamiliar insects observed in the growing crop so that immediate action can be taken to deal with any new trouble before it is too late and the pest or disease becomes permanently established and eradication is no longer possible.

POLLINATION OF THEOBROMA CACAO *L.* IN TRINIDAD, B.W.I.

By D. J. Billes, B.Sc., A.R.C.S.

Introduction.

In view of its increasing importance in the light of recent discoveries considerably more attention has been paid during the past few years to the subject of cacao pollination. Although evidence on the method of pollination has accumulated, it is still not conclusive. Early workers were content to suggest that self-pollination occurred either in the bud or with the aid of wind. These theories have since been discarded because the former assumption was not founded on fact while the sticky nature of the pollen and the structure of the flower render wind pollination unlikely. That cross-pollination occurs and that both flying and crawling insects are involved, has been definitely established, but comparatively little is known regarding the actual agents of pollination. It is only now that what is believed to be one, at least, of the most active insect pollinating agents has been discovered. This pollinating agent which is described in this paper may be of considerable importance especially in relation to the phenomenon of pollen incompatibility since it may well prove one of the limiting factors in yield. Voelcker (10) in 1938 rather dramatically summed up the results of investigations on this subject as follows: "the murder has been proved by incontestable circumstantial evidence but the murderer and his technique await the opening of another chapter." It can be claimed that a start has now been made on that chapter.

Review of Literature.

Opinions are divided as to the method of pollination. Most investigators have concluded that insects are the only agents of pollination. Harland (5) and Stahel (9) have blown on and shaken flowers to simulate wind action but have never transferred pollen to the stigma. Jones (6) has enclosed flowers in an insect-free cage in a breezy position but obtained no setting. In a similar experiment by Stahel a set of one cherelle was obtained from nearly 500 flowers, but this was not stated to be conclusive evidence that setting could occur without the agency of insects. That both flying and crawling insects are involved in pollination has been shown by Harland (*loc. cit.*), Stahel (*loc. cit.*) and Posnette (7), who isolated trees from crawling insects by sticky bands. Stahel showed further that ants and aphids are likely pollinators. Caracciola (1) studied the habits of ants, flies and thrips in flowers and concluded that only thrips had the habits essential to cause pollination. Efforts, however, to prove the pollinating ability of the thrips did not succeed. Wright (12) agreed with this hypothesis and further support was given by Cope (3) who showed a significant positive correlation between the setting intensity and density of thrips population in the flowers. This correlation was also positive for ants but negative for aphids. This last observation conflicts with Stahel's results.

Despite the evidence against wind pollination, that view is still held in Java. Van Hall (4) in 1932, although he mentions the investigations of Stahel and Harland, still favours the possibility that pollen could fall from anther to stigma merely with the aid of the wind. He is supported by Wellensiek (11). The chief objection of these writers to the insect pollination theory, is that insects visiting cacao flowers are too few to cause the observed amount of pollination which, according to Wellensiek, might fluctuate up to 47 per cent. of the flowers.

No mention has been made of the possibility that water might assist pollination but all agree that unaided self-pollination is impossible.

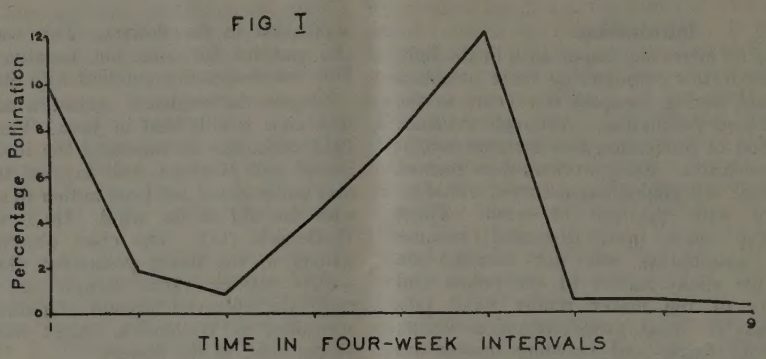
Water-Pollination.

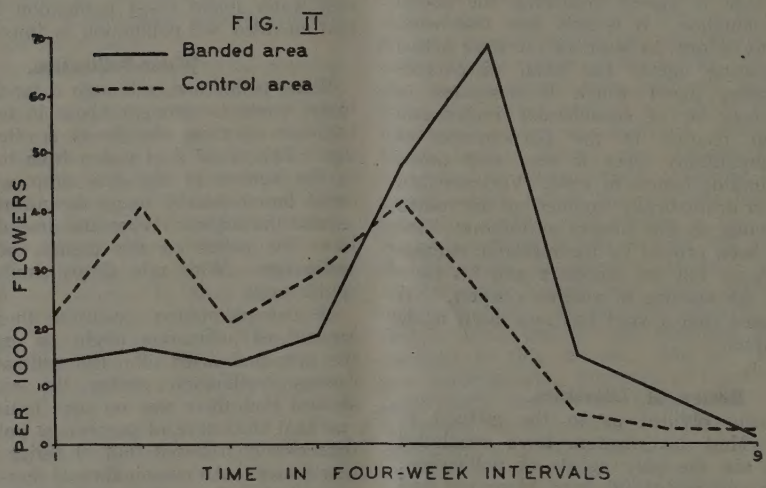
Water-pollination, although a far-fetched possibility, could be brought about in two ways. In the early morning the flower is often filled with dew. This could float pollen from the petal hood to the bottom of the dew drop which, as the cacao flower usually hangs downwards, would be around the stigma. When the drop dries it would leave the pollen on the stigma and thus cause pollination. With rain drops similar conditions could result.

If dew-pollination occurred then an initial amount of pollination might be expected when the dew had dried off. But estimations of percentage pollination during the early morning showed that there was no such initial pollination and that the curve of percentage pollination with time closely followed that of thrips migration to new flowers. An examination of dew-laden flowers showed that the anthers had not burst. Estimations of percentage pollination before and after rain showed no difference and so rain had no effect, either detrimental or favourable. This was confirmed experimentally by filling flowers with water and leaving them to dry. Again, no pollination was observed.

Wind-Pollination.

Observations on the setting intensity and percentage pollination of flowers over a season have shown no correlation with the force of wind. Thus in the dry season, when there is the greatest amount of wind, the setting is at a minimum. Shaking a flower causes pollen to fall from the petal hood but the stigma is protected from this by a palisade of hairy staminodes and thus pollination is prevented. The hypothesis was further tested by enclosing flowers on self-compatible trees in insect-free cages and by blowing on and shaking flowers and examining them to see if pollen had been transferred to the stigma.





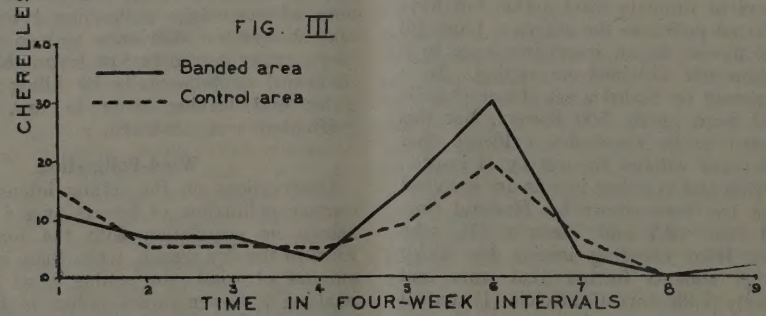


FIG. I.—Percentage Pollination at four-week Intervals from 28/8/40 to 28/4/41.
FIG. II.—Setting Intensity of Self-compatible Trees from 28/8/40 to 28/4/41.
FIG. III—Setting Intensity of Self-incompatible Trees from 28/8/40 to 28/4/41.

Conditions in a muslin cage are always abnormal and wind action is certainly reduced. But 1,212 flowers gave no cherelles although many were shaken to resemble wind action. That setting was possible in the cage was shown by the fact that two out of five hand pollinations were successful. When insects were allowed to enter by means of a small hole, which would have no effect on the movement of wind inside the cage, setting occurred naturally. A very large number of flowers was shaken and blown upon, both gently and forcibly, and in only three cases was pollen transferred in sufficient quantity to cause successful fertilisation. In these cases, all from the same tree at the same time, pollen was produced abundantly and there were scarcely any hairs on the staminodes. Attempts with other flowers from the same trees failed. It can be concluded that the amount of natural pollination caused by the wind, which in a well regulated plantation is reduced to a minimum, would be quite negligible.

Insect-Pollination.

Since wind and water have been shown to be ineffectual in causing pollination, insects must be responsible. Certain preliminary deductions can be made on the rôle of insects as pollinating agents. The ability to cause pollination primarily depends on the habits of insects whereas the efficiency further depends on adaptive structures, such as the hairy bodies of many bees. When the amount of pollination is low, as in cacao, it may be due to a common but inefficient insect pollinator or to an efficient but uncommon one. This probably explains why pollination has never been seen, because the observation of the common insects has not taken place over a long enough period and uncommon insects have been disregarded.

A survey of the insects which visit cacao flowers, and their approximate relative and seasonal abundance, was conducted from the middle of 1939 to the middle of 1940 by Professor A. M. Adamson and Dr. E. McC. Callan. The pedicel of the flower was cut so that the flower dropped into a tube of alcohol. This procedure was successful in catching even wary flies, but led to an inaccuracy in the estimation of the aphid population in the flowers as most aphids are found on the cut pedicel. Collections were made at irregular intervals from four widely separated estates.

The results of the survey showed that the thrips, *Frankliniella parvula* Hood, and the aphid, *Toxoptera aurantii* B. de Fonsc., were by far the most common insects in the flowers. The thrips population fluctuated between a high peak in the early wet season and dropped to nearly nil in the early dry season, and on the average was more numerous during the wet than dry season. The aphid population appeared to differ little between wet and dry seasons. In addition there was another group of insects only one-tenth as common as the preceding, and consisting of ants of various species, chiefly *Wasmannia auropunctata* Rog., gall midges, and leaf-hoppers or nymphs of Jassids and Membracids. Lastly there was a miscellaneous group consisting of rarer insects and spiders. The total number of species of insects collected was under 30.

Harland (5) and Stahel (9) isolated trees from crawling insects by means of a sticky band and so showed that flying insects were involved in pollination. A similar but more complex experiment was carried out over a long period of time, from September, 1940 to April, 1941. Branches, one from each of 11 self-compatible and 8 self-incompatible trees, were banded with Ostico, a proprietary grease-banding substance, and each week a count was made of flowers and new cherelles on these branches and on untreated control branches. The results are presented graphically in Figs. II and III and a comparative graph of percentage pollination is given in Fig. I.

Only the last peak in the curve of percentage pollination is represented in the curves of setting intensity. This might be due to the deleterious effects of a spray which was used in the beginning of the experiment to remove crawling insects from the banded branches. The curves of the control and banded area of the self-incompatibles were similar and the total setting intensity of each was the same. Thus one can conclude that flying insects alone are responsible for cross-pollination. But the curves for the self-compatibles were rather erratic and dissimilar although the total setting intensities of the banded and control areas were again nearly the same. It was therefore not possible to conclude that flying insects were the only important self-pollinators. Crawling insects which are common but inefficient pollinators can have a two-fold effect. Whereas a certain amount of pollination might be caused by them, they might lower the general level of pollination by scaring away more efficient pollinators. Aphids and particularly their attendant ants might have this effect which would explain the absence of peaks, or low peaks, in setting intensity, which are shown by the control areas at interval 6 in Figs. II and III where cross-pollination is at a maximum. This experiment shows the importance of flying pollinating agents and indicates that a crawling self-pollinating agent is present.

The next step undertaken was the elimination of those insects whose habits and structure precluded them from causing pollination. It was found that a large majority of the insects which had been collected in the survey merely rested and remained on the outside of the flower and so never had the opportunity of collecting pollen. Thrips and one of the rare insects, *Forcipomyia* sp., both flying insects, commonly carried pollen and, since they walked about the flower, they were probable agents of pollination. Aphids, although quite common on flower stalks and cushions, comparatively seldom entered the flowers and only

the young nymphs moved about to any extent but were often seen sprinkled with pollen. Although the nymphs of Membracids and hunting spiders were seen to carry pollen, both were uncommon and so seldom bore pollen that any pollination attributable to them would be negligible. This applies to all other insects observed. Ants, in particular, never carried more than one or two scattered grains of pollen.

Direct proof that an insect is a pollinating agent can be obtained by watching the actual event or by enclosing the insect in a cage with flowers. Resultant setting would be caused by the insect as it has been shown that flowers in insect-free cages do not set. Supporting circumstantial evidence can be obtained by correlating natural fluctuations of setting intensity with the fluctuations of population of the insect as was done by Cope (3). Stahel (9) showed that the percentage pollination of aphid-inhabited flowers was higher than that of uninhabited flowers and thus, unless either aphids attracted another pollinator or were attracted by pollinated flowers, they caused pollination. The method could be applied on a larger scale and to other insects.

An estimation of the percentage pollination of thrips-inhabited and aphid-inhabited flowers was made from September, 1940 to April, 1941, and compared with the percentage pollination of insect-free flowers. This experiment served not only the immediate purpose but gave a constant opportunity for the observation of the actual process of pollination. It was found that the peaks of pollination were in the beginning of September and the beginning of January. One depression was in November and the minimum was during March and April. The September peak coincided with a very high population of thrips in the flowers whereas during January the thrips population had fallen and *Forcipomyia* was more common. Throughout the period the percentage pollination of thrips-inhabited flowers was higher than that of uninhabited flowers and when the thrips were numerous, the difference was most marked. The individual restlessness of thrips, and consequent scattering of pollen, is increased when many are together in the same flower. The results for aphids were variable. Sometimes they were most efficient and at others appeared detrimental to pollination. Very often aphids were not found in flowers for long intervals and thus one could conclude that they are, on the whole, unimportant pollinators. Pollination of insect-free flowers was often found to be effected by a neat mass of pollen as described by Harland (5) and Stahel (9). These masses were found to be deposited by *Forcipomyia*.

The most important results obtained from this experiment were actual observations of the act of pollination. Two pollinations were caused by aphid nymphs. Once a nymph of a Membracid, *Cymbomorpha* sp., and once an adult Membracid, *Horiola picta* F., deposited pollen on the stigma, but only in small amounts. A caterpillar once deposited pollen but these caterpillars usually consume the flower they inhabit. Pollination by thrips was not observed. Once, however, a small mass of pollen in which was a thrips seta, was seen on the stigma of a thrips-inhabited flower. That was strong evidence that the thrips had transferred the pollen. The process of pollination by *Forcipomyia* was not seen but direct proof of its ability was obtained, when a *Forcipomyia* caused the pollination of a flower with which it was confined in a glass tube. This was the only pollinator observed to carry pollen from flower to flower and tree to tree. The bundles of pollen deposited are so typical that a flower visited can easily be discerned.

An attempt was made to prove the pollinating ability of certain insects by enclosing them with a flower in a pollination tube as described by Pound (8). Aphids caused both pollination and setting and this gave further conclusive proof of the ability of aphids to transfer pollen. The other insects experimented upon were thrips, yellow ants, mealy-bugs and leafhoppers but the treatment so upset the habits of these insects that no results were obtained. They wandered about the tube and would not enter the flowers.

Notes on *Forcipomyia* sp.

Although rare, this Ceratopogonid has been collected from many cacao estates in Trinidad. Specimens were determined as *Forcipomyia* sp. by Dr. A. Stone of the United States Department of Agriculture. The size is approximately 1 mm. and the colour a greyish brown. The antennae, bearing whorls of setae, and the short, stout legs and hairy wings enable this fly to be distinguished from others found in cacao flowers. The breeding place has not been discovered but is probably in damp, decaying vegetation as that is usual for the genus. The fly only seems to occur during the wet season, from July to January.

The habits of this *Forcipomyia* sp. are curious. Males are very occasionally found resting on the outside of the flowers but it is not known whether they are of the same species as the females under discussion. The females wander about the flower with a purposeful intent as if they were searching for something. During this search they enter the petal hoods and accumulate, directly from the anthers, a mass of pollen on the rounded thorax which bears small setae, ensuring the stability of the pollen. After a period of from three to six minutes the *Forcipomyia* walks to the periphery of the flower and flies often to a flower on a tree some distance away. The curved shape of the staminodes is so adapted that when the fly walks down them, the stigma automatically scrapes the pollen from the thorax. Since this may happen whenever the fly alights on the staminodes or walks over them, there is ample opportunity for pollination and it makes up for the rarity of the insect. In fact, far from it being as Cheesman (2) stated in 1932, "that the cacao flower is adapted

for the prevention of pollination", the structure is perfectly adapted for pollination by *Forcipomyia* and particularly for cross-pollination.

The reason for the search of the female throughout the flower was not discovered. Because males remain on the outside of the flower, a mating search would not explain the wanderings inside. In the laboratory two individuals were confined in a small glass dish with other small insects found in cacao flowers to see if a search for prey was the reason. No interest was shown but the artificial environment might have inhibited the natural instincts. But whatever the reason, it is most important for the natural pollination of cacao.

Notes on the Cacao Flower Thrips, *Frankliniella parvula* Hood.

The cacao flower thrips has been found in cacao flowers and on flush leaves and in the flowers of coffee, bananas and many weeds found in cacao plantations. It has not been seen on mature cacao leaves and only feeds on cacao flowers and flush leaves, and the floral parts of some other plants. This thrips is quite distinct from the red-banded cacao thrips, *Selenothrips rubrocinctus* Giard, which causes damage of economic importance to the leaves.

When it became probable that it was a major pollinating agent, the life history and ecology were studied. The duration of the life cycle is approximately two weeks. Abbreviated details are given below.

Mating and Oviposition. — Neither was observed. Oviposition in the laboratory took place at night. The eggs were laid in flush leaves through a small cut in the lower epidermis.

Egg Stage.—This lasted four days. The young larva emerged through the epidermal cut.

Larval Stage. The larvae can be recognised by their brownish-orange colour and have only been found on flush leaves and, rarely, flowers. They are very active and it is probably this quality which renders them immune from attack by *Dasyscapus parvipennis* Gahan, a parasite introduced into Trinidad from the Gold Coast for the control of *Selenothrips rubrocinctus*. The larval stage lasts six days.

Prepupal Stage. — This was not discovered naturally but almost certainly occurs in the soil. Mature larvae entered cracks in the soil if offered in captivity. The stage lasts approximately 36 hours.

Pupal Stage.—Again, this was not discovered naturally. It lasts about two days.

Very large fluctuations of population in the flowers occurred throughout the year and these could not be correlated with climatic factors. At times nearly every flower seemed to be occupied by thrips and at other times they were completely absent. A few weeks after the beginning of the wet season was a period in which the thrips reached their greatest numbers. The range was often from 50 thrips per 200 flowers to over 400 thrips per 200 flowers, followed by a fall to the original level, all in the space of four weeks. Soon after the onset of the dry season the thrips population in the flowers dropped to zero. These fluctuations could be related to flushing and flowering intensity, both of which also fluctuate. There is nearly always a certain small amount of flushing in a plantation but at intervals nearly all the trees will flush at the same time. The only occasions which are predictable are the early wet season flush and the early dry season flush. Flowering intensity does not change so violently, but is usually high during the early part of the wet season and decreases during the early dry season. When there is no flushing the thrips are confined to the flowers and there can be no increase in population. In fact, the need for migration every one to three days when the flower abscisses will result in a constant mortality, as a fresh flower has to be found before starvation ensues. When a general flush occurs it forms an accessible and relatively permanent food supply and so denudes the flowers of thrips. This effect will be most marked when flowers are scanty and so explains the early dry season minimum. On the flush leaves a great increase in population will occur and, when the flush hardens, this increased population will have to migrate to the flowers, causing a large, though temporary, increase of the population in the flowers. This was observed after a dry season flush and explains the early wet season peak. Thus, flushing will increase the population but a high flowering intensity is necessary to maintain the population. When flowering and flushing are negligible as happens in old plantations, the alternative food plants, the weed flowers, will maintain a small residual population which could take advantage of more favourable conditions.

Review and Conclusions.

Coupled with the experience of previous investigators these experiments show that pollination only occurs through the agency of insects. The only insects which are either sufficiently efficient or sufficiently numerous are the pollination midge, *Forcipomyia* sp., the cacao flower thrips, *Frankliniella parvula* Hood and the aphid, *Toxoptera aurantii* B. de Fonsc. Other insects might occasionally cause a negligible amount of pollination through chance scattering of the pollen.

Forcipomyia was rarely seen but the abundance of the typical pollen masses showed it to be an important pollinator. Pollination of this type was very unevenly distributed over an area, the branch to branch and tree to tree variation being considerable. This explains the intense bursts of setting occasionally observed on trees. Although in a large sample of flowers the *Forcipomyia* type of pollination was seldom above 50 per cent. of the total pollination, this proportion would not indicate its relative importance.

Not only is a large amount of pollen deposited at each pollination but *Forcipomyia* is the only pollinator observed to carry pollen from flower to flower and thus to serve as a cross-pollinating agent. *Forcipomyia* and the typical pollen masses were not seen in the dry season and it is significant that self-incompatible trees do not set fruit at that season (3).

Whereas *Forcipomyia* causes a large amount of pollination at short periods, the thrips and aphids would cause a constant small amount of pollination. Although it has not been disproved that the thrips are cross-pollinators, it is almost certain that they are not so or only to a small degree. They often carry an appreciable amount of scattered pollen on their bodies but much of this is shed when they vibrate their wings preparatory to flight. It is doubtful therefore whether they could carry sufficient pollen to cause cross-pollination. Aphids are so sedentary that it is quite impossible for them to cause cross-pollination. Thus one would expect self-compatibles to show a rate of setting which varied but never reached zero—at least while aphids and thrips were present—whereas the setting of self-incompatibles would often fall to zero. This is approximately what happens. It is not considered a feasible proposition to endeavour to increase the setting intensity and decrease its variation by acting through the pollinating agents.

Providing a self-compatible tree produces flowers, almost certainly some pollination would occur and if *Forcipomyia* was present, a certain amount of cross-pollination would ensue. But self-incompatibles depend not only on their flowering, but on the presence at the appropriate time of both self-compatible flowers and *Forcipomyia*. This involves a considerable risk and, where flowering is periodic and not continual throughout the wet season, such trees are liable to be low setters and, depending on the actual amount of setting and the nutritive status of the tree, low croppers. In old plantations there are many trees of this kind. Imperial College selections contain many incompatibles but many of these characteristically flower intensely over a long period and so obtain a sufficient amount of cross-pollination. The adverse factors against self-incompatible trees would tend to become intensified with age as mature trees tend to flower periodically at definite times. If *Forcipomyia* is absent at those times or if a subsequent physiological disturbance causes considerable cherelle wilt, then either a small crop or none at all will be produced. Thus the total crop from a plantation might be controlled to a greater extent than is realised by the vicissitudes of the self-incompatible element through the effect of pollination and physiological disturbances.

Summary.

1. The method of pollination of cacao in Trinidad has been investigated. Pollination has been shown to occur only through the agency of insects.

2. The important insects involved in self-pollination are *Forcipomyia* sp., the cacao flower thrips, *Frankliniella parvula* Hood, and the aphid, *Toxoptera aurantii* B. de Fonsc.

3. Flying insects alone have been shown to be involved in cross-pollination. The only probable agent of cross-pollination is *Forcipomyia* sp.

4. The effect of pollination on the yield of self-compatible and self-incompatible trees is discussed.

Acknowledgments.

I wish to acknowledge and convey my thanks to Professor A. M. Adamson and Dr. E. McC. Callan for carrying out the insect survey and for their continued advice and to Professor E. E. Cheesman and Mr. R. de Verteuil for much information derived from their personal experience of cacao. I am also indebted to Dr. A. Stone (through the courtesy of Dr. C. F. W. Muesebeck, United States Department of Agriculture) for the determination of the Ceratopogonid as *Forcipomyia* sp.

Literature.

(1) Caracciola, H. A. 1910.—The Pollination of the Cacao Flower. Agric. Soc. of Trinidad and Tobago, Paper No. 439.

(2) Cheesman, E. E. 1932.—The Economic Botany of Cacao. *Tropical Agriculture*, Vol. 9, No. 7, Supplement.

(3) Cope, F. W. 1940.—Agents of Pollination in Cacao. *9th Annual Report on Cacao Research* (1939), pp. 13-18.

(4) Hall, C. J. J. van. 1932.—Cacao, *2nd. Edit.* Macmillan, London.

(5) Harland, S. C. 1925.—Studies in Cacao, Part 1. The Method of Pollination. *Ann. App. Biol.*, 12, pp. 403-409.

(6) Jones, G. A. 1912.—The Structure and Pollination of the Cacao Flower. *West Indian Bulletin*, 12.

(7) Posnette, A. F. 1937.—Incompatibility and Pollination in Cacao. *MSS. Dissertation* in Library of I.C.T.A., Trinidad.

(8) Pound, F. J. 1935.—Note on a Method of Controlled Pollination of Cacao. *4th Annual Report on Cacao Research* (1934), pp. 15-16.

(9) Stahel, G. 1928.—Beitrage zur Kentniss der Blutenbiologie von Kakao. *Verh. Koninkl. Akad. Wetensch., Amsterdam, Afdeeling Natuurkunde (Tweede Sectie)*. Vol. 25, No. 6.

(10) Voelcker, O. J. 1938.—Cacao. A Summary of Literature since 1931. *7th Annual Report on Cacao Research* (1937), pp. 20-30.

(11) Wellensiek, S. J. 1932.—Bloembiologie waarneningen van Cacao., *Arch. voor de Koffiecultur in N.E.I.*, 6th Jaar, No. 2, July.

(12) Wright, H. 1907.—*Theobroma Cacao* or Cocoa. Its Botany, Cultivation, Chemistry, and Diseases. Ferguson, Colombo, 1907.

THE BANANA IN CENTRAL AMERICA.*

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I. CULTIVATION.

The most traditional portrayal of banana cultivation is perhaps that in which an Oriental sage, sitting in pious contemplation in the shade cast by the plant, contentedly leaves it to its own devices in the knowledge that it will flourish and bear fruit for himself and for generations to come. In the early days of banana growing in Central America, the grace of Nature likewise played a prominent part in the inception of what was to become a major industry. By the middle of the nineteenth century it was known that the Gros Michel banana—now the principal variety of commerce—not only would grow but would grow marvellously on the rich soils of the Caribbean islands and mainland. It only remained to be demonstrated that the fruit, if harvested while still green and somewhat immature, could be transported to distant markets, even by sailing ship, and the stage was set for a characteristic display of American enterprise. On the fertile alluvial flats of Central America wonderful bunches of fruit were soon being produced in what was then considered large quantities, with the promise of infinitely more to come; railroads were being laid through forest and swamp; in due course the clipper gave way to the steamship, and the latter to the specialized, modern refrigerated 'banana boat'. It is a tale of more than ordinary fascination, not wanting in its record of blood and sweat, violent competition, diplomatic ingenuity, chicanery, folly and disaster, but one, be it said, telling of an agricultural industry, which, despite many vicissitudes, has enjoyed a great measure of prosperity and continued success.

The general procedure in establishing a plantation was almost incredibly simple. Large areas were roughly surveyed, sometimes, as shown by experience, very inadequately, and work on the construction of roadways commenced at once. The underbush of the virgin forest was cutlassed sufficiently to allow the laying out of the rows, the position to be occupied by each stool or plant being marked out by a stake. Suckers or 'bits' of the underground banana rhizome were then planted in holes 15 inches in diameter and 15 inches deep. The tall forest trees were then felled, creating unbelievable havoc and seemingly unconquerable confusion; but experience had shown that after two or three months the young banana plants would begin to appear through the mass of trunks, branches and twigs. As both the growth of the young plants and the decay of the forest debris take place with great rapidity under the prevailing humid tropical conditions, very soon, with occasional cutlassing of the secondary bush around the young plants, an orderly plantation is established and bunches of fruit may be reaped within the year.

In those early days of banana growing, faith in the unbounded and unending productiveness of rain-forest soils had not been shaken by crop failure or the epidemic spread of disease. Accordingly, scientific procedure had not been consciously applied to this new industry. Thus, an area might be surveyed as to its boundaries but anything in the nature of a modern soil survey was almost invariably conspicuous by its absence. This must not be taken to infer that the early explorers for banana land did not know their job. On the contrary, like the early Spanish settlers throughout the Caribbean, they were pre-eminently successful in searching out areas possessing outstanding fertility. But extensive areas of uniformly high fertility were considerably more rare than those early land explorers could possibly assess from the limited surveys they were able to make of vast areas of swamp and rain-forest; as a result, in the ambitious planting schemes so characteristic of this new and remunerative industry, large areas were utilized which were quite unsuited to the exacting requirements of the Gros Michel banana, or which, at best, could only be profitable for a limited period.

The passage of time showed that the extensive areas of virgin land which had been taken into cultivation throughout Central America could be roughly classified into three categories: (1) poor soils on which production fell off after four to seven years; (2) intermediate soils, probably with some initial defect in fertility, which deteriorated to the point of abandonment in the course of 10 to 14 years; and (3) good soils which could be cropped continuously, in many instances without replanting, for more than 20 years. In parenthesis it may be mentioned that some areas in the Republic of Honduras have been supporting first-class stands of bananas, without replanting for at least 40, possibly 50, years.

As to what now seems such an evident necessity, the need for good drainage, more often than not this was completely neglected. Provided standing water was not actually in evidence, a plantation was considered to be sufficiently well drained. Again, where irrigation would certainly have been

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attended with good results, this obvious requirement was not infrequently neglected. Here then, in brief, are some aspects of banana cultivation in Central America that might have been observed some 20 to 50 years ago.

Recent years have witnessed many notable changes. The method of establishing a plantation (that is, planting, felling and brushing) is still as before. Before the planting programme is considered, however, a careful and sufficiently detailed soil survey is carried out and unfavourable areas eliminated from the scheme. The general topography of the areas is also studied in order to establish, as economically and effectively as possible, the roads, railroads and tram-lines essential to the rapid handling of fruit, while drainage schemes not only take cognizance of the needs of particular localities but also may extend to the lowering of the level of swamps, the digging of canals and the dredging of rivers. In fact, it has often been said (by the engineers) that banana growing is much more a feat of civil engineering than of orthodox agriculture. Lastly, it may be added that extensive levees are thrown up where necessary to fend off flood water from productive areas.

Such operations as those described above are typical of the advances which have been made during the past 20 years. The development of the technique of irrigation in areas where the rainfall is insufficient or badly distributed is of particular interest. Irrigation is, in fact, a major problem: it involves the construction of main channels and subsidiaries, sometimes over very considerable distances; the building of sluice gates; and in some instances the pumping of all water from wells and rivers. Lastly, a supply of sufficiently intelligent labour must be recruited to effect the surface irrigation of the plantations. It will be readily appreciated that there is more in successful irrigation than meets the eye; uniformity of application, avoidance of erosion and of water-logging, judging irrigation cycles and quantities, costing, and, not least, adequate drainage, all being relevant to the task.

It is in respect of irrigation that one of the most interesting of innovations in banana cultivation is to be seen to-day. This consists in a replacement of surface by overhead applications, water being supplied to plantations by powerful pumps at the rate of 3,500 gallons a minute. The actual distribution is effected by rotating overhead nozzles or projectors, possessing an effective radius of about 70 yards, that is, each projector sprays approximately three acres (Fig. 1). The tall 'risers', that is, vertical 5-inch pipes which convey the water up to the projector nozzles are spaced throughout the plantation as required (Fig. 2). The complete equipment, comprising a power house, two large pumps, 14-inch mains, sub-mains and laterals, thus represents a very considerable mechanical intrusion into the leafy greenery of a banana plantation. The results achieved have been very satisfactory. As to the working method, overhead irrigation is applied continuously for several hours at a time; the duration of each application is such as to provide the equivalent of several inches of rain, thus achieving the effect of a heavy, sustained, tropical precipitation. From a point of vantage the spectacle presented by the system in operation is quite remarkable, the great arcs of water, slowly swinging round, gleaming in the bright sunlight, or being resolved into miniature rainbows.

It need scarcely be said that such extensive projects have been the subject of careful costings. Notwithstanding the initial capital expenditure, the results obtained, as judged by increased production of fruit, decrease in labour costs, &c. have been such as to justify the experiment, and the system is being extended. Factors which require consideration include the fertility and probable duration of production of the area, the status of Panama disease (*Fusarium oxysporum cubense*) and its liability to rapid spread, and the proximity of adequate water supplies for pumping.

Overhead irrigation has not only proved successful as a commercial venture, but several important results, probably not anticipated, have also accrued. Not least is the fact that this method of supplying water has greatly facilitated agricultural operations on heavy clay soils, effecting, it is thought, an actual improvement in the tilth over a period of time. Further, it has made it possible to utilize for banana cultivation soils of much higher clay content than had hitherto been deemed possible or advisable. This is a very important consideration, since clay soils have not only proved productive of good fruit, but are also 'resistant' to the inroads of Panama disease. To what extent the conquest of clay will eventually be extended by overhead irrigation in conjunction with other innovations, is a question that cannot fail to command the attention of all interested in tropical agriculture. It will suffice to say that a high standard of production is to-day being obtained on clay soils which 20 years ago would have been omitted from any well-considered planting programme.

A characteristic of the cultivation of the Gros Michel on heavy clay soils is that the initial growth tends to be somewhat tardy, so much so that planters may be induced to think that their venture has been ill-advised and destined to failure. Experience has shown, however, that if fertilizers are applied during the first few months, the initial lag is greatly reduced; plants improve progressively with age, especially after the foliage canopy is established, and consistently good yields may be obtained. Such detailed attention to potentially productive areas is now part of the working policy of the larger companies and is in sharp contrast to the method of exploitation followed by abandonment of former days. The aim, in brief, is the highly commendable one that all sections of a farm shall be so worked in respect of fertilizing, pruning, spacing, &c., as to make for a good general standard of productiveness.

FIG. 1.—*Overhead irrigation of bananas in Honduras.*

FIG. 2.—*Young banana plantation showing 'riser' for overhead irrigation.*

FIG. 3.—*Harvesting of fruit, Honduras.*

(*All photographic blocks illustrating this article have been loaned by courtesy of the Editors of "Nature" to whom our thanks are due.* Photos by I. M. Smith.)

FIG. 4.—*Banana plantation immediately after dusting by aeroplane.*

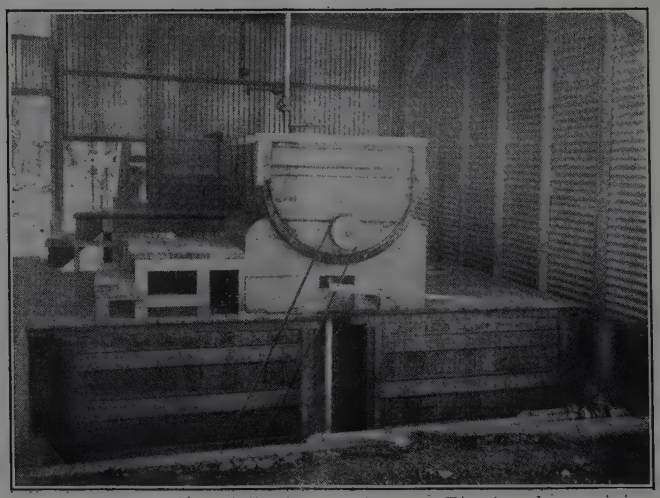

FIG. 5.—*Preparation of Bordeaux Mixture. The two large mixing tanks (each 2,000 gal. capacity) with the lime degritter above. In the background the copper sulphate tank can be seen.*

FIG. 6.—*Inside the mixing shed. The operator is standing on the platform above the large mixing tanks; right, the lime degritter; left, the copper sulphate soaking tank.*

FIG. 7.—*Spraying plants of medium stature.*

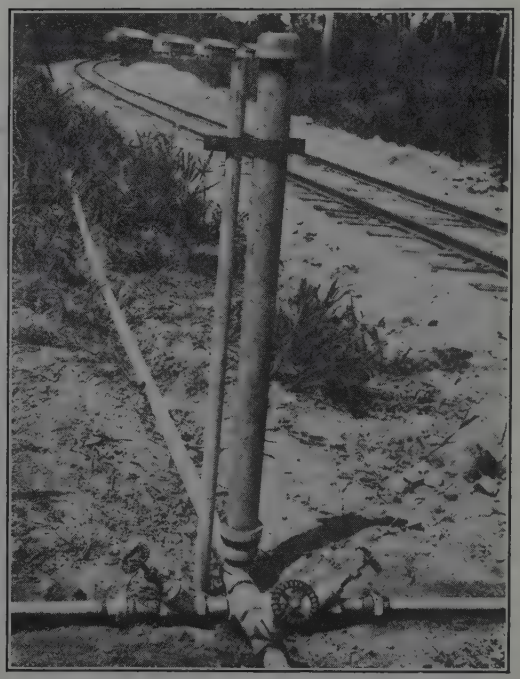

FIG. 8.—*Part of the pipe-line system with stand-pipe.*

FIG. 9.—*Removal of spray residue. The nearer bunch is being dipped in the acid bath; the further bunch is being drained before going into the water baths.*

FIG. 10.—*Scene at fruit depot. The counterpoise apparatus for dipping bunches is seen in operation.*

Reference has been made to the losses periodically caused by floods. These inundations are violent but usually of brief duration. They may prove exceedingly destructive, taking a heavy toll not only of plants and fruit, and leaving plantations a wilderness of smashed vegetation smeared with several inches of mud, but also permanent railroads and bridges may be swept away. The path of the flood water is determined by topography, fertile areas in the river bends being especially subject to inundation and erosion.

A recent experiment of very considerable interest and practical value lies in the utilization of the silt-laden flood water, which is contained and controlled by channels and levees in such a way that its burthen of earthy matter is deposited in selected low-lying areas. Each flood—and several may occur in one year—thus results in the deposition, in swampy areas, of several inches of friable and fertile top soil, eroded from higher up the valley. In a surprisingly short space of time—a few years at most—hitherto valueless low-lying areas are so built up that they can be drained and planted with bananas. This useful work is now being undertaken on a not inconsiderable scale.

In the banana lands of the Ullua River (Republic of Honduras) such reclaimed areas can be seen to-day. They are supporting excellent stands of young plants, and the incidence of Panama disease was, as observed by me at the beginning of 1940, negligible. Such innovations are of the greatest significance in the agricultural development of Central America. They mark the transition from the impermanence and rough-and-ready exploitation of other days to the rational utilization of natural resources and to that permanence which should result from a system which aims at the maintenance of a high standard of productivity in favourable localities. To the consumer on distant markets, such preparations for the future also bring the assurance that there will be no abatement in the supplies or quality of the product to which he has become accustomed.

Some 15 to 20 years ago, with the abandonment of vast areas on account of Panama disease and deterioration of fertility under continuous single crop cultivation, the question was frequently mooted as to the fate of the banana industry when all the good virgin areas became used up. The question is still asked and it may now be answered. So far as Central America is concerned, there seems no reason for supposing that production will seriously decline for many years to come. In recent years, there has not only been adequate production on the major properties, but actually over-production of bunches of the first quality. Extensive areas, mapped for banana growing, have not yet been touched, other new and highly productive areas are being developed on a very conservative scale, and, as indicated above, existing plantations are not only being maintained in first-class condition but also are being daily added to by the control of flood water.

To the agriculturist as to the layman, the spectacle of a modern banana division, comprising some 60 square miles under cultivation, with surface and overhead irrigation provided where necessary, and supplied throughout with a pipe-line system for the application of Bordeaux Mixture (used to control Cercospora leaf disease), is one that engenders confidence for the future. To those who have been responsible for such notable achievements, and for much courageous experimentation on a grand scale, great credit is due.

II. THE CONTROL OF CERCOSPORA LEAF DISEASE.

The leaf spot disease of bananas caused by *Cercospora musae*, Zimm., though widely distributed in the Indo-Malayan and Australian regions, was not recorded in the western tropics until 1934. During the brief period of two or three years from its first recognition in Trinidad (1), it had appeared with epidemic intensity in many of the Caribbean islands and on the mainland of Central and South America, and by its destructive effect on plantations showed itself to be a disease of first-class economic importance. In the Republic of Honduras, where successful control measures were eventually worked out, as described below, the disease was first definitely recognised towards the end of 1935, at which time the intensity of infections suggested a development period of perhaps 12 to 18 months. The data available, unfortunately, throw little light on the question as to how this malady was introduced into the Caribbean or whether its spread took place from one or several centres of infection.

Briefly, the disease manifests itself as a profuse spotting of leaves; the tissue around the spots begins to die rapidly, and large, coalescing dead patches appear, so that in severe infection the leaf may be more or less completely destroyed. Bunches borne on affected plants show slow or arrested growth, behave abnormally during development and subsequent ripening, and commercially are valueless. (2)

The success eventually achieved in Central America in controlling leaf disease is to be viewed in relation to previous work undertaken in Australia. The literature up to 1935 shows that no control measures had, in fact, been worked out. (3) In particular, dusting and spraying with fungicides had not met with the desired measure of success. Removal of infected leaves, fungicidal treatment of suckers, different spacings of plants and the growth of cover crops, all yielded results which were either negative or uneconomic.

When Cercospora leaf disease became established in the vast banana plantations in Central America the economic losses, within a very short time, were formidable, and it was evident that some measure of control *must* be secured if a major agricultural disaster was to be avoided. Only those who have ridden for hours through miles of scorched, brown

plantations, with extensive defoliation in progress, and everywhere small worthless bunches ripening on the plant, and who, by contrast, have seen the leafy greenery of a first-class plantation in full production, can appreciate the havoc wrought by this new malady as it waxed to epidemic proportions.

Here indeed was a challenge. The scientific staff of the principal fruit company spared neither labour nor expense in an effort to determine whether or not thorough dusting or spraying, repeated as each new leaf appeared, would give protection against the disease. For it should be noted that a monocotyledonous plant such as the banana, which produces its complement of some 12 to 15 large leaves one by one at intervals of two to three weeks, according to growth conditions, presents a problem of unusual difficulty when it is a question of securing adequate spray coverage on a majority of the leaves. The work of Stahel, (4) on *Cercospora musae* as it affects the Congo banana in Surinam had shown that only the young leaves in the centre of the foliage crown were susceptible, and hence, for thorough protection, each new leaf should be sprayed as it emerges from the top of the pseudostem and begins to unroll. Actually, more recent investigations have shown that the older leaves of the Gros Michel are also susceptible; but this only adds to an already exacting task and justifies the present procedure in Central America of spraying plants right through to the harvesting of the bunch. The problem confronting banana growers, then, was twofold, namely, the application of dust or spray fungicide over vast acreages, and the frequent treatment of plants of all ages throughout the year. Truly a formidable task and one, moreover, to which it seemed improbable that there could be an economic solution.

As the programme of experimental work was steadily pursued, the epidemic took an ever-increasing toll of plantations, and it was evident that the industry was faced with the most serious crisis of its history. Or, as one writer, with characteristic Latin-American emphasis, put it "Leaf disease has made a dwarf of Panama disease". At length it began to be apparent, though final confirmation was far from having been obtained, that by spraying plants in short cycles of two to three weeks, that is, as new leaves emerged, with Bordeaux Mixture and other copper-containing preparations, a considerable measure of protection against leaf spotting was achieved. At this point the whole situation had become so critical that it seemed desirable that action should be taken on the preliminary results obtained, and the courageous decision was reached to install stationary spraying apparatus on a gigantic scale, the equipment to include power-houses, large spray-mixing tanks, pumping units and the materials for an ample pipe-line system extending right through the plantations. It was eventually found that a block of seven to eight hundred acres made a satisfactory unit for a single spraying 'project', several such units being necessary on each large banana division. On the Ullua River (Republic of Honduras) there is to-day a continuous area of 36,000 acres (about 60 square miles) under permanent pipe-line spray control. Altogether, in Central America, more than 100,000 acres are now equipped with stationary installations. Once again, the industry is in a state of high productiveness, and notwithstanding the heavy expenditure on spraying equipment and on the machinery for overhead irrigation, good profits are being made. The control of leaf disease probably represents one of the greatest achievements in the history of phytopathology.

Before proceeding to an account of the equipment and its manipulation, reference may be made to the subject of fungicides. Many have now been tried and in various degrees have been found to possess practical value. By all tests and criteria, however, experience in Central America has consistently pointed to Bordeaux Mixture as the most satisfactory fungicide for the control of leaf disease.

Reference may also be made to dusting by aeroplane. Briefly, spray has proved superior to dust: the latter is quite expensive and does not give the same certainty of control as spraying does. In practice, dusting by aeroplane is rather a tricky business, and, moreover, the period each day when applications can usefully be made is very brief; that is, in the early morning while dew still remains on the leaves. Dusting by aeroplane probably has its place, however, in those areas where the extent and duration of productiveness do not warrant the installation of permanent, stationary equipment (Fig. 4).

It should also be mentioned that the methods of cultivation used in plantations in Central America largely, if not entirely, preclude the operation of mobile spraying units, since the plantation floor is strewn with decaying stumps and logs, is rough and irregular in the absence of mechanical tillage, is overgrown with vines and shrubby vegetation, and is dissected by deep drainage ditches and in some instances by irrigation canals.

The spraying equipment, which now constitutes such a characteristic feature of banana plantations, has been derived, with modifications dictated by experience, from that used in United States orchards. Driving power for the pumps and mixing tanks is provided by a 40-50 h.p. Diesel engine. A spray pump, of the three-cylinder vertical type, with a capacity of 60 gall. min. at 600 lb. pressure and a speed of 120 r.p.m., has been found adequate for an 800-acre block operating on a 14-day spraying cycle. It may be noted that the high pressure under which the spraying fluid is maintained is of the greatest importance in providing a good coverage. Side by side with the power house is the mixing house where the spray is prepared. Bordeaux Mixture having come into general use as the most effective

fungicide, the equipment of the mixing house has been specially designed to make its preparation as simple and efficient as possible. The two main mixing tanks, each of 2,000 gallons capacity, are provided with four propeller agitators with a central bearing. The warehouse floor, tank tops and the floor of the railway car (in which materials are delivered) are all on the same level, thus facilitating the handling of materials and economizing labour. Situated above the two large tanks is a smaller tank described as a lime degritter (Fig. 5). Of approximately 300 gallons capacity, it is provided with an agitator which can easily be started and stopped. In this tank the proper quantity of lime is mixed with 250 gallons of water and vigorously agitated for as long as possible. Then, before use, during a period of five or more minutes, the grit is allowed to settle and the milk of lime drawn off through a 2-inch pipe which projects some three inches above the bottom of the tank. The copper sulphate solution is prepared in another tank which is divided into four compartments each of 200 gallons capacity (Fig. 6). Each compartment is fitted with a tray which holds the bluestone and descends some four inches into the water. For 2,000 gallons of spray of standard strength (that is, 5-5-50), 200 lb. of copper sulphate would be placed in one of the trays; at tropical temperatures this quantity will dissolve in about two hours. Mixing can be continued indefinitely by using the soaking tanks in rotation. The charge of copper sulphate solution is led into the large mixing tank through a 1.25-inch brass pipe, header and rubber hose. In Honduras, the method used in the preparation of Bordeaux Mixture is to add dilute copper sulphate solution to concentrated milk of lime. The latter is therefore run into the mixing tank, and the former, diluted to the required extent in a swirl box by the addition of water from a 3-inch hose, is added.

The pipe system used for the distribution of Bordeaux Mixture from pump house to plantation consists of 2-inch mains, 1.25-inch laterals, and 0.75-inch sub-laterals, all suitably galvanized. An economic and effective layout of pipes is designed separately for each project. As an indication of the scale of a typical unit it may be mentioned that main lines may extend to 10,000 feet, laterals to 4,000 feet, and sub-laterals to 800-1,000 ft. The spacing between sub-laterals may range from 160 feet to 240 feet, this being determined by local factors such as the position of open drains and the conditions of the plantation floor. The actual installation of these extensive pipe-line systems has been accomplished by quite inexperienced labour, recruited locally. The pipes are simply laid on the ground. As to the very considerable detail relevant to mechanical aspects, blockages, deterioration, &c., it need only be said that each and all are the subject of careful study, and that a special repair and maintenance squad is constantly at work, supervising, testing and where necessary effecting desirable changes. The actual distribution of spray is by means of hoses; these are attached to the delivery pipes and dragged here and there over a limited area as required (Fig. 7). Eight to ten hoses may be in operation in one small area and each spray gun may be opened and closed several times per minute. In these circumstances it is evident that very rapid changes in pressure may take place in the system: the undesirable effects which would normally result have, however, been satisfactorily overcome by the insertion at suitable intervals of vertical stand pipes (Fig. 8); these are three inches in diameter and four feet high; the air cushions which they provide reduce water hammer and effect a balancing of pressure at the delivery nozzles.

Spraying operations are carried out by local labour. Members of the spray gang are always conspicuous by the whitish blue deposits of Bordeaux Mixture on their hats and shirts. They take a great pride in their work and describe themselves with all due solemnity as 'chemists'. The effective spraying of bananas is not an easy task: every stool includes plants of three ages (that is, the oldest plant bearing a more or less well-developed bunch, its immediate successor also a tall plant, and a still younger follower); and there may be as many as 300 to 500 stools per acre. To lack of uniformity in the height of plants to be sprayed is added a further difficulty in that in plantations more than five or six years old the plants are very irregularly distributed. The leaf itself offers still further obstacles in that its waxy surfaces, vertically or steeply inclined when young, are not easily wetted. Nevertheless, all these difficulties have been overcome. Each stool is thoroughly sprayed from four positions, the jet being directed just below the top of the highest leaves (30 to 40 feet above the ground), the lower leaves being adequately wetted by the downwardly drifting spray. Details of the construction of spray guns need not be entered on here; the essential point to be noted is that, at the high pressure used, the Bordeaux Mixture is applied as a veritable fog, the coverage afforded being surprisingly good and very effective. At the end of each day's work, the pipe-line system is washed out and left full of clean water.

The use of Bordeaux Mixture necessitates the removal of the spray residue from the fruit. This is effected by dipping freshly harvested bunches in a dilute acid bath followed by thorough washing in water—a procedure which removes the detritus accumulated during growth and therefore improves the appearance of the fruit (Figs. 9 and 10).

Installation, operation and maintenance have been the subject of careful costing. The control of leaf disease, involving as it does continuous spraying throughout the year at intervals of two to five weeks, is, of course, expensive. Nevertheless, experience has shown that the costs can be met and that considerable profits can be made. Most important of all, an epidemic disease which threatened a major industry with extinction has

been conquered—an achievement which must be highly gratifying to those who have been associated with this notable phase of tropical agriculture.

The control of leaf disease has many aspects. A few of these may be briefly noted here. While leaf disease can be controlled by the application of copper-containing sprays, knowledge of meteorological conditions, rate of development of leaves, and of the seasonal intensification of the disease, is necessary in order that control measures may be undertaken at minimum cost. In fully grown plantations, the control of severe leaf disease is difficult and costly, and, as a rule requires a considerable period of time to achieve. Experience has shown that the best procedure is to cut down all plants in affected areas and to secure control as the young plants come up. Considerable difficulty has been experienced in obtaining control in young plantations situated in close proximity to severely affected areas; instances are known where control could not be obtained until the adjacent diseased plantations had been cut down. Since adult leaves as well as young ones are susceptible, it is considered advisable to spray the entire stool thoroughly on each occasion, continuing through to the harvesting of the bunch. Good spray coverage means good control; the best coverage is obtained when properly prepared spraying liquid is applied under high pressure. In regions where growth is rapid control is sometimes difficult to obtain; a close spraying cycle is then necessary, and should only be widened when sufficient knowledge of the local behaviour of the disease has been obtained. Spraying makes for an increase in the bunch weight, but injury due to scale insects is intensified. Pruning of spotted leaves not only serves no useful purpose but even accentuates the effects of the disease. The fact that bad areas must in some instances be cut down before control in adjacent areas can be obtained is an indication of the important part played by the locally produced spore population.

Satisfactory as the position now is in respect of commercial control, it is generally admitted that costs are still too high, that many aspects of the disease, including the effect of soil and climate are still imperfectly understood, and that research work on a comprehensive basis should be consistently pursued.

III. PANAMA DISEASE.

During recent years in Jamaica and Central America the spread and intensification of leaf disease of bananas, *Cercospora musae*, Zimm., has tended to deflect public attention from another epidemic disease of long standing and of great economic importance, namely, Panama or wilt disease, caused by the soil-borne fungus, *Fusarium oxysporum cubense*. To-day the question is often asked as to which of the two diseases presents the greater danger to the industry. During 1935-40, an observer, surveying the almost incredible damage wrought by leaf disease in such a brief space of time, and aware of the much slower spread of wilt disease, might well have been tempted to regard the former as the greater evil, assuming that he did not take refuge, as Sir Roger de Coverley almost certainly would have done in the circumstancess, in the view that there was much to be said on both sides. Among the more enlightened members of the planting community, however, the opinion is held that wilt disease is the more serious problem since leaf disease can be, and is being, controlled, whereas wilt disease cannot. From the investigational point of view leaf disease, while not a simple problem, nevertheless is not beset with those complications which are inseparable from the activities of soil pathogens and whereas it is known that bananas resistant to wilt disease can be obtained by hybridization the work is slow because of technical difficulties. So far, indeed, no hybrid has been obtained which possesses the many qualities which have made the Gros Michel the commercial banana *par excellence*. Moreover, it is apparent that some considerable time must elapse before such a hybrid is produced. In some respects, therefore, the Panama disease situation remains very much what it has been for many years. The disease, of course, has continued to spread and has led to the discontinuation of banana growing in many areas.

The passage of time has not lessened the many curious and unexplained aspects of Panama disease. Some instances may be cited. Perhaps one of the most surprising situations is to be found on the lower Ullua River in the Republic of Honduras, where, notwithstanding periodic inundations by flood water carrying débris from affected areas higher up, large areas have remained in a high state of production, with a negligible amount of wilt disease, for a period assessed at 50 years. By contrast, areas inland from La Ceiba have been seriously affected by disease within two years of planting. There, the evidence is suggestive of a pre-cultivation dispersal of the pathogen during the periodic flooding of the forests adjacent to the river, wilt disease having been observed in areas scoured by the flood water higher up. On being planted with bananas, such areas have rapidly gone out with disease. Many instances are known of the 'resistance' of older areas and the 'susceptibility' of new. Whether conditions on the floor of virgin forests are specially favourable for the propagation and distribution of *F. cubense* has not, so far as I am aware, been investigated in detail, but the evidence strongly suggests that they are.

A particularly obscure problem is presented in certain areas which for many years have appeared to possess 'resistance' to the disease but which suddenly begin to be seriously affected. Dispersal of the pathogen by flood water is not involved and so far the nature of the factor which is

operative has not been ascertained. An increase in the pathogen population doubtless bears a direct relation to the increasing incidence of the disease, but relevant data are scanty or absent.

On the controversial question as to whether fresh outbreaks are principally due to contact with neighbouring diseased plants or are the result of new sporadic infections, little can be added save that numerous instances of both abound in those areas where the disease is making headway. It has been observed that spread by contact takes place more rapidly in some soils than in others: the more open the texture and the more acid the soil, the more rapid is the spread of disease. Alternatively, clay soils and slightly alkaline soils appear to possess more 'resistance' to the disease. This information has now been available for some years (5), and recent observations would seem to bear it out. On light riverside soils, for example, the spread of disease from foci of infection may be particularly rapid. Recent years have also shown that clay soils, for many years considered 'resistant,' have eventually shown an even more rapid spread—a phenomena for which no adequate explanation has so far been forthcoming. Other areas are also known which, after many years in an almost disease-free state, are now becoming rapidly affected. The collective experience, practical and scientific, in Central America is that hydrogen ion concentration is the master factor determining the severity of Panama disease, followed by texture; but, as Reinking's work shows, distribution of the pathogen and density of its population in the soil obviously require careful consideration (6).

The Panama disease situation in Central America is being closely watched, and on the properties of the larger companies every effort is being made to check its spread and to test out any new idea which might eventually have some economic value. An unusually interesting and important experiment is in progress at the present time. This consists in flood-fallowing an area of about 100 acres which had previously been put out of production by Panama disease. The area has been empoldered and divided into four sections, each to be kept submerged for a different period of time. The maximum period of inundation will be eighteen months. This experiment is based on the facts that soil fungi such as *Fusarium cubense* require oxygen to live, and that, when highly infected soil was submerged for one month under two feet of water, no *F. cubense* could be found in it. The outcome of this experiment will be awaited with the greatest interest by all associated with the extensive alluvial banana lands of Central America. Already it has been found that in new land, built up by the sedimentation of controlled flood water, and therefore subjected to several inundations, the incidence of Panama disease has been negligible. This may be considered as an indication of the probable success of flood-fallowing, but time alone will tell. A successful result will obviously have an important bearing on the whole question of banana production in the Caribbean.

References.

1. Wardlaw.—*Trop. Agriculture*, **xi**, 7, 173-175 (1934).
2. Wardlaw, Leonard and Barnell.—*Trop. Agriculture*, **xvi**, 6 (1939).
3. Wardlaw.—"Diseases of the Banana", Chap. XV, Macmillan (1935).
4. Stahel.—*Trop. Agriculture*, **xiv**, 9, 257-264 (1937).
5. Wardlaw.—"Diseases of the Banana", Chap. III. Macmillan (1935).
6. Reinking.—Several Papers summarised in (1) above.

SUGAR FROM SORGHUM.

By discovering means of removing starch and aconitic acid from the juice of the sorgo plant, used extensively for making sorghum syrup, scientists of the United States Department of Agriculture have developed a method for obtaining a satisfactory yield of sugar crystals which may be made into refined or granulated sugar. Sorgo sugar has been produced only on a semi-industrial scale, and studies now must be conducted by the Bureau of Plant Industry to find varieties best suited for sugar production, and where sorgo can be most profitably grown.

Research on the present project was begun two years ago under the direction of H. S. Paine of the Bureau of Agricultural Chemistry and Engineering. Studies directed towards starch removal have resulted in simple methods that worked successfully on a pilot-plant scale. The cane is double-milled and the raw juice is centrifuged, removing from 3 to 10 pounds of starch per ton of cane. The centrifuged juice is then treated with lime, heated and allowed to settle in a conical tank. The clear juice at the bottom is drawn off and the scum on the top is forced through a filter press to recover the juice it contains.

This leaves a small amount of starch which must be removed; otherwise the syrup would jell instead of crystallize. By treating the juice at this stage with a very small amount of an enzyme, pancreatic amylase, the remaining starch is converted to products which do not seriously interfere with crystallization of sugar. Satisfactory percentage recovery of sugar per ton of sorghum cane was obtained. After removal of starch and aconitic acid from the juice, it can be put through the process customarily used for production of cane-sugar.

Starch and aconitic acid both have important commercial uses and are expected to be valuable by-products which will assist in reducing the net cost of the sugar. Aconitic acid, produced synthetically, is now being used in the manufacture of plastics.—(*News Edition, Ind. & Eng. Chem.*, Vol. 18, No. 24, page 1136, 1940.)

SOIL INVESTIGATIONS IN CUBA.*

AMONG the papers read at the 1939 Conference of Cuban Sugar Technologists, one by B. R. Arguelles constitutes a plea for a clearer recognition of the objectives which the various analyses commonly undertaken have in view. The various features of the several determinations forming the stock-in-trade of the analyst are very briefly discussed from this aspect.

The survey of Cuban soils by Bennett and Allison in 1927 was, with a supplementary survey, responsible for the identification of 128 soil types. The basis of the classification is colour—black, brown and red ; but within these three groups sharp differences are found in suitability for the culture of cane. In a paper entitled "The Influence of Colour on Soil Productiveness", C. E. Beauchamp sets himself to answer the question, does any difference exist in the productive capacity of these soil groups based on their colour ? The answer is given by an analysis of the replies received to a questionnaire, circulated to all centrals by the Department of Agriculture, from which the percentage of black, brown and red soils, as well as the average yield of fall cane, was obtained for most of the plantations. Official reports were also enlisted to supply figures of yields of cane and sugar for the two years 1937 and 1938, together with the average yields of these for the 5-year period to 1938.

The data thus accumulated were first grouped into 21 groups according to the percentage area occupied by the three colour types of soil, the unit being in each case taken as 20 per cent. Thus, 11, 8 and 5 were the number of plantations cultivating soils which were respectively entirely (100 per cent.) black, brown or red. Intermediate stages are represented by the group, composed of 11 plantations, having 40 per cent. of the soils black, and the remainder (60 per cent.) brown ; and by the group of eight plantations having 40 per cent. of the soils black, 40 per cent. brown, and the remaining 20 per cent. red. A series of diagrams were then prepared in which the three angles represent the 100 per cent. unit of the three colours and the respective bases the zero percentage, the four intermediate (20 per cent. difference) points marking the intermediate positions in the manner of the Schreiner triangle. Into such triangles the sum of the yield figures for cane and sugar is inserted at the appropriate intersections and arrows indicate the incremental direction between all neighbouring points of intersection. From these directional arrows indices are obtained for each type of soil colour the respective index being the number of arrows pointing towards the angle representing 100 per cent. of that colour.

The first graph illustrates the position with regard to yield of plant fall cane in 1938, and the respective indices are: black 23, brown 14, and red 8. Interpreted in terms of soil condition, this is taken to indicate that the black soils, being the younger, are less friable and porous than brown, and these, again, than red. In the above order they exert a retarding effect on seepage and hence on the leaching of soluble minerals. Later graphs illustrate the cane yield (all cane) for 1938, 1937 and the 5-year average ending 1938. In the first of these, the indices are black 14, brown 21, and red 10 ; in the second, black 18, brown 14, and red 13. The 5-year average, however, shows a very different position. The indices here are black 13, brown 14, and red 18. Interpreted in terms of the crop, these figures indicate that black soils, though producing a high tonnage as plant cane, undergo some change which renders them less favourable for ratoon crops. Two possibilities are suggested for this behaviour of the black soils ; either, though the supply of plant nutrients in them may be adequate, their physical conditions are unfavourable for root development or the rate of restoring the available nutrient supply is inadequate for the later growths. The brown soils appear to be better with more stable physical conditions, while the red soils, though physically excellent for sugar cane, have a lower potential fertility due to the readiness with which leaching takes place in spite of the high rate of restoration of the available nutrients. That the physical condition is the more important factor is suggested by the fact that black soils, generally speaking, do not respond to fertilizers while red soils do.

When attention is directed to the yield of sugar (96°) a different result is obtained. For the 1938 crop the indices are, black 14, brown 11, and red 20 ; for the 1937 crop they are, black 15, brown 9, and red 21 ; whilst for the 5-year average they are black 12, brown 12, and red 21. It would appear from these figures that the lowest cane producing soils yield the highest return of sugar and *vice versa*. The explanation of this is traced to the phenomenon of maturity ; cane on the poorer soils has a relatively limited growth and matures earlier and, when age is used as the determinant for cutting, yields the heavier return of sugar. The practical problem of the red soils is to determine how, by the use of irrigation, fertilizers and so on, to increase the cane yield without reducing the high sugar yield.

The conclusions here arrived at are, it is pointed out, in contradiction to earlier findings of the writer and others, that any treatment favouring a higher cane yield will result in a higher sugar content. As he points out, the contradiction lies in failure to consider the effect of maturity.

In the present study consideration is given to a single factor, the colour of the soil. This is not the only character and, as Bennett and Allison had shown, within these major groups a large variety of soil types exist. The same method

* Proceedings of the 13th Annual Conference of the Associacion de Tecnicos Azucareros de Cuba, 1939.

of analysis applied to these subsidiary types may well lead to information which would disclose means for increasing field yields and sugar output.

The same author (C. E. Beauchamp) contributes a further paper entitled "The Composition of the Alcoholic Extract of Sugar-Cane Leaves as a Means of determining the Fertility of the Soil for this Crop". In recent years many endeavours have been made to use the plant as its own analyst. That, in fact, is the idea underlying field experiments. Here, however, the idea is different. The plant itself performs the initial stages of the analysis through its selective absorption of the essential nutrients, and the analyst in the laboratory performs the later stages in determining the amount of the different nutrients absorbed under the varying conditions of supply. This method of analysis may be said to be still in the experimental stage, the difficulty lying in the selective distribution of the absorbed nutrients in the vegetative tissues of the plant. It remains to be determined what tissues should be used in the determinations ; these may be different in different plants, for the sugar cane is not the only crop which has been used for the purpose. In the sugar cane particular attention has been devoted to the leaf. The present author with his associates has earlier used the chlorophyll content of the leaf. H. Lagatu and L. Maume, in a series of papers in French journals, used the entire leaf ; W. Thomas used the entire foliage. Wheat, potato and tobacco were used in the course of these experiments. The selective distribution, not only in the tissues but in accordance with age, has been pointed out in Mauritius in the case of the sugar cane. The general conclusions drawn by these authors are that positive correlations exist between the mineral composition of the entire leaves of crop plants and their yields, and that the final yield is positively correlated with the total quantity of the mineral elements present in the leaves and with the proportion in which they are found.

In the present paper the alcoholic extract of the cane leaves is studied, but the concepts of Thomas, Lagatu and Maume are adopted, though in their case the basis is the entire leaf. These concepts embrace the "intensity of nutrition", this being the sum of the percentages of N, P_2O_5 and K_2O and, for the proportion of these three nutrients, "the N-P-K unit", representing the ratio of each one of the three to the sum total expressed in milligram equivalents × 100. Having three variables, diagrammatic representation is possible by the triangular method used in the preceding paper. The fertilizer treatments compared are combinations of: N, 4 and 8 ; P_2O_5, 4, 8 and 12 ; and K_2O, 0, 4, 8 and 12.

The yields, both of crop and sugar, resulting from these various treatments together with the detailed analyses for N, P_2O_5, K_2O, Ca and Mg content, as well as the intensity of nutrition figure, the sum of the first three of these, are set out in detail. The first conclusion is that the figure for the intensity of nutrition bears an intimate relation to yield whether in terms of crop or sugar content and where no increase in the intensity of nutrition occurred, the yield of crop and sugar content remains stable. Further, the relative proportions of the three fertilizer elements, expressed in terms of the N-P-K unit, exerted a material influence on yield whether of crop or sugar. Increments of potash resulted in a gradual increase in the intensity of nutrition with correspondingly high yields, such increments producing a corresponding reduction in the nitrogen content.

The effect of increments of nitrogen in the fertilizer was less uniform. Such increments, when the potash content was low, increased the intensity of nutrition and, at the same time, increased the potash content of the N-P-K unit ; but when the potash content was high, such increments of nitrogen reduced the intensity of nutrition and decreased the potash content of the N-P-K unit. This effect was traced into the figures for sugar content, for an increase in the intensity of nutrition due to a nitrogen increment in the fertilizer did not affect the sugar content adversely whilst a decrease of the intensity of nutrition for the same reason led to a decrease of the available sugar content.

In these experiments potash appears to be the most important nutrient ; definite information with regard to phosphorus was not forthcoming, as it would appear that the soils involved were adequately supplied with this element. Since these determinations were made on cane in its early stages of growth, it is suggested that such analyses would give positive information on the deficiencies and fertilizer requirements of different soils taking into account the need not only for increasing the intensity of nutrition but for equilibrating the N-P-K unit. Further applications lie in the determination of the differential requirements of varieties and in the ascertainment of the effect on yield on any factors which may positively or negatively affect the growth of cane in the field. — (*The International Sugar Journal*, 1941, Vol. XLIII, No. 1, pages 6–7.)

H. M. L.

HOT WATER TREATMENT OF SUGAR-CANE CUTTINGS.

Germination was hastened, growth of the sprouts was stimulated, and control of the chlorotic streak disease was favoured by soaking sugar-cane cuttings in hot water at 50 to 52 C°, for 20 to 25 minutes. The treatment killed all insects, either within or on the cuttings, and produced much more rapid germination and growth of shoots than did dipping the freshly-cut ends of the seed pieces in one per cent. ceresan solution.—(*Chemical Abstracts*, Vol. XXXIV, No. 3, Cols. 844-5.)

THE SUPPLY OF HUMUS TO SOILS.

The supply of humus to soils is sometimes confused with the replenishment of soil-nitrogen, and the value of composting methods is then measured in terms of nitrogen content. The rôle of humus is specific, and composts should not vary widely in composition from natural soil organic matter. To save waste, additional nutrients should be applied separately, according to the special needs of each crop. Organic preparations rich in nitrogen should be classed as *top dressings* rather than as humic composts, which are intended to maintain a healthy physical condition in soil, so ensuring an optimum environment for physico-chemical and micro-organic activities congenial to crop growth.

Nitrogen recuperation in Indian soils is rapid, and except in areas of high rainfall, minerals are ample for the crops usually grown. Both in Bihar soils growing indigo and in the Malwa black cotton soils, low yields or crop failures appear to be due mainly to the *deterioration of soil texture*, as a direct result of monsoon conditions. A recent experiment at Indore showed that *by merely preserving an open texture in the soil, yields of Indian cottons could be doubled and of American varieties trebled.* The present capacity of soils to nourish crops should be utilized thoroughly before the question of the addition of nutrients arises. Agriculture in tropical and sub-tropical areas—both old and new—has a long way to travel to reach this stage.

Plants require a solution of inorganic nutrients in the soil as well as in the culture-jar. No organic plant food is necessary. *It is primarily its power to create and maintain healthy soil texture that enables humus to increase the soil's efficiency in producing such solutes,* whether from its own components or from applied manures. It is apparent, also, that humus serves as a self-adjusting container for these nutrient solutions. Aided by these beneficent functions it is natural that crops should enjoy freedom from disease.

For the maintenance of fertility under arable conditions, the requirements of soils for humus varies. It is high in humid and irrigated areas of luxuriant growth, but very low in arid zones, which is fortunate for dry-land farmers, because the possible natural sources of replacement are scanty. Transport difficulties disappear when sufficient compost can be made in the field from its own crop residues by a modification, such as the rain-watered process described.

Recent trials at Indore show that the permeability of black cotton soils is nearly doubled when dressed with compost, an important factor in reducing erosion. Losses of nitrogen are reduced. A steady supply of nitrified nitrogen is assured, both on black soils and also on sandy soils. (*See* tables.)

In the cotton crop, this leads to fuller boll-development and double or treble yields, according to variety. The first step in reducing cotton production costs must, therefore, be *efficient utilization of all wastes for humus manufacture.*

The authors feel confident that suitable adjustments in composting can easily be made for any conditions, if care is taken to preserve intact the fundamental conditions favourable to the right type of micro-organic activity. (F. K. Jackson, Y. D. Wad and V. G. Panse, *Institute of Plant Industry, Indore, Central India, Bull.* No. 2.)

(A) The Influence of Compost on Soil.

	Relative permeability of soil.	Nitrified Nitrogen found under Monsoon Conditions (Mg. per 100 g. of soil)			
		No. of days after application			
		21	42	63	109
Heavy black cotton soil:					
(i) Without compost	1.0	1.93	2.32	1.98	1.03
(ii) Compost added at 1.4 tons/acre = 17 lb. N/acre	1.7	2.30	4.95	3.45	2.63
Light sandy soil (Jaipur):					
(i) Without compost	—	1.32	—	—	0.52
(ii) Compost added at 1.4 tons/acre = 17 lb. N/acre	—	4.90	—	—	1.52

(B) The Influence of Compost on the Yield and Development of Malvi Cotton.

	No. of Plants Observed	Average Yield of Seed Cotton (g. per plant)	Average No. of Mature Bolls per plant	Weight of Seed Cotton per boll (g.)
Black cotton soil:				
(i) Without compost	85	3.9	3.5	1.10
(ii) With compost	73	9.1	5.0	1.79

REVIEW.

THE DISEASES OF THE COCONUT PALM.

By H. R. Briton-Jones. *Bailliere, Tindall & Cox*, London. 10s. 6*d*.

The author of this book was Professor of Mycology and Bacteriology at the Imperial College of Tropical Agriculture, Trinidad for ten years and the manuscript was compiled only a short time before his death in November 1936. It was not possible to arrange for its publication immediately after his death but the Imperial College of Tropical Agriculture is to be congratulated upon its decision not to permit the manuscript to remain unpublished in its archives. It was arranged that the text should be revised and brought up to date with a view to publication. This revision was done by Professor E. E. Cheesman, the Professor of Botany at the College, who in the foreword to the book acknowledges the valuable collaboration he has received from Mr. R. E. D. Baker, the Senior Lecturer in Mycology at the College.

The publication of this book on the diseases of the coconut palm will be welcomed by all concerned with tropical agriculture and in particular by coconut estate proprietors and managers and by those officers of Departments of Agriculture who are responsible for extension work amongst, and instruction to, the large numbers of small holders throughout the tropics to whom the coconut is an all important crop. The book is well printed on good paper and is properly illustrated. That it should have been found possible to proceed with its issue during war time is a testimony to the confidence and enterprise of the publishers.

It was around 1906 that the diseases of the coconut began to attract attention from scientific workers in the tropics. The world demands for increased supplies of vegetable oil had stimulated an extension of planting and of production. It was found, however, that considerable losses of palms were being experienced in the groves and plantations in both the old and the new world. In certain areas, these losses were heavy and serious. To ascertain the causes of the deaths which were taking place amongst coconut palms was necessary before remedial measures could be devised. Work was started almost simultaneously in the West Indies and in India and Ceylon. From thence onwards research with the diseases of the coconut palm has been carried on continuously and as the result of recent work many of the views which were formerly held have been discarded and a much clearer picture of the causes of many of the diseases to which the coconut palm is prone under certain conditions has been constructed.

The author refers to the work of the earlier investigators and indicates where subsequent research has either confirmed or proved incorrect the conclusions reached. He also reviews the results of the work of more recent workers and shows where further knowledge is still required. In certain instances he permits himself to indulge in speculations where gaps in our knowledge occur and whilst these speculations may not be fully substantiated when further scientific research has been carried out they should be stimulating to plant pathologists working in the tropical sphere.

Chapters of the book are devoted amongst others to the bud-rot complex, bronze leaf wilt, *Phytophthora* bud-rot, red ring disease, stem bleeding disease, root diseases, leaf diseases and nut fall. A useful bibliography has also been compiled and included. Control measures, when practical, are discussed and when these are thought not to be economic it is clearly indicated. A large amount of useful information has been collected and discussed in this book. There is however still more to be learned, particularly in regard to the physical conditions and the water relationships of soils on which coconuts thrive and it is to be hoped that plant pathologists, biochemists and soil chemists, will in the future collaborate together in the elucidation of some of the problems which are yet unsolved.

To coconut estate managers, agricultural officers, students of tropical agriculture and plant pathologists and physiologists, this book is commended. It is informative and should stimulate further thought, investigation and research.

F. A. STOCKDALE.

NITROGEN-POTASH-SUNLIGHT RELATIONS OF SUGAR CANE.

The object of this experiment was to see whether the effects of sunlight and fertilizers are interrelated. For this purpose, cane plants fertilized with different amounts of nitrogen and/or potash were exposed for different lengths of time to sunlight.

The data obtained show that different exposures to sunlight have very different influences on the effect of different applications of nitrogen. Under full sunlight conditions, high nitrogen gave increased cane yields which were only slightly, if at all, of poorer quality than were obtained from a more moderate amount of nitrogen. On the other hand, when the time of exposure to sunlight was decreased, the high nitrogen not only did not increase the cane yield, but it definitely produced a cane of poorer quality and less sugar content. Under full sunlight, the sugar yield was adversely affected only when the amount of nitrogen used was excessive.

This result definitely suggests that, when cane is grown under conditions where sunlight is apt to be deficient, high nitrogen applications must be avoided or maximum sugar yields will not be obtained.

No evidence was secured to indicate that extra potash applications would prove beneficial where inadequate sunlight conditions exist. However, if extra nitrogen applications are to be given, it would appear to be wise to accompany them with extra potash, since there appears to be a point of balance between these two nutrients which can have a special effect on juice quality.—(*Sugar*, 36 No. 3 ; 1941.)

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Cause and Nature of Overliming Injury.

Experiments carried out at the Vermont Agricultural Experiment Station showed that deleterious overlimed soils fixed large amounts of borates in a form unavailable to plants, which appears to be the cause of overliming injury. Increasing rates of liming caused increasing amounts of boron to be fixed until free lime was present. Borax was found to benefit the following crop plants suffering injury from excess lime: rape, alfalfa, flax, vetch, lettuce, tomatoes, beets, onions, buckwheat, sweet, red, white and Ladino clovers, poppies, cabbage, turnips, radishes, celery, spinach, apple trees as transplants and potatoes from tubers. The borax is best applied broadcast at the rate of 10-40 lb. per acre.—(*Chemical Abstracts*, 34, p. 7509.)

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Volcanic Ash as Source of Silica for Silicification of Wood.

Volcanic ash is a rich source of readily-available silica for geochemical processes, and the common association of silicified wood with volcanic ash is regarded as the result of a genetic relationship arising from the alterability of the ash. Silicified wood may serve as an indicator for volcanic material in sedimentary deposits. Occurrences of silicified wood in the United States have been listed and classified. — (*Brit. Chem. & Phys. Abstrs.*, A. I. 1940, p. 396.)

* * *

Rapid Determination of Moisture in Soil.

A method of determining the moisture percentage of soils without the necessity of securing soil samples is greatly needed. If some simple, quick method of determining soil moisture percentage without securing samples were available, the problem of irrigation control would be simplified. The standard procedure for determining soil moisture is to dry a sample of soil in an oven for 24 hours. This procedure is too slow. With this method, information as to the amount of available water in a grower's field frequently arrives too late to be of maximum value. After investigating several rapid methods of determining soil moisture, one developed at the Michigan Agricultural Experiment Station was found to be the most accurate and rapid. It consists of pouring 20-30cc. of alcohol over 20 grams of soil and burning the alcohol. The heat and washing action of the alcohol drives off the moisture in the soil. By weighing the sample before and after burning, the amount of moisture that sample contained is determined. By this method, a moisture analysis can be made in 10 to 15 minutes. A carrying case, fitted with scales, aluminium receptacles for burning the alcohol, and an alcohol supply, has been supplied to members of the agricultural department so that information on soil moisture can be obtained in the field, if necessary. A single soil moisture determination for a field is usually of little value. It is the trend of the movement of moisture in the soil that is important. Therefore, all moisture records kept by the Spreckels Sugar Company are charted so that the trend of extraction of water from the soil can be visualized. Soil moisture determinations are important and necessary for proper irrigation practice.—(*Facts about Sugar*, 35, No. 10, p. 35.)

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Fermentation of Ceylon Tea.

The term 'fermentation' is understood in the tea industry to mean the enzymic process during which 'black tea' develops its aroma and colour. After harvesting the partly dried leaf is broken up in a rolling machine, whereby some of the juices are worked out from the leaf and form a varnish-like coating on the surface. This rolling or crushing starts fermentation which may be allowed to continue for several hours. The initial green colour of the crushed leaf changes during this time to a coppery-red tint. The tea is then dried, cleaned and graded. It has been known for some time that this fermentation involves oxidation of polyphenols in which oxidases, peroxidases and catalases are concerned. The substrates include tannins, catechins and polyphenols (catechol, gallic acid) so that the whole process is very complex. Since tea leaf contains a much higher amount of polyphenolic substances than is usual in plant tissues, it would not be surprising if it contained also enzyme systems with rather specialized functions. J. Lamb and H. B. Sreerangacher (*Biochem. J.*, 34, 1472; 1490) now show that tea leaf preparations show marked specificity in the oxidation of ortho-dihydric polyphenols, without the activation of peroxidase, the primary oxidation products being probably orthoquinones. The system possesses the power of forming aniloquinones in the presence of quantities of potassium cyanide which are known to inhibit peroxidase activity. The system may be a parallel to the ascorbic acid-ascorbic oxidase and the cytochrome C—cytochrome oxidase systems in other plants, where a specific oxidase catalyses the initial changes of a series of reactions. —(*Nature*, 147, 3722; 1941.)

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Relation of pH to Growth in Citrus.

The growth of citrus trees in artificial solution cultures was found to be affected by the pH of the medium in which the roots grow. Greater and healthier growth was made in acid than in alkaline solutions. Experiments indicate that much of the advantage of ammonium sulphate fertilization for citrus fruits over that of $Ca(NO_3)_2$ or KNO_3 fertilization is due to the fact that ammonium sulphate leaves an acid residue which lowers the pH of the soil.—(A. R. C. Haas.)—(*Plant Physiol.* 15, 377-407.)